ENVIRONMENT

Should $PM_{2.5}$ Regulation Be Decentralized?

Particulate controls yield large benefits in some places and bizarre policies in others.

BY DAVID KEMP AND PETER VAN DOREN

The health benefits of reducing emissions of particulate matter are a significant justification for the regulatory state. From 2006 to 2016, the Office of Management and Budget reported that Environmental Protection Agency (EPA) regulations accounted for at least 71 percent of total monetized benefits and 55 percent of total monetized costs of all major federal regulations. Air quality rules specifically resulted in 95 percent of the estimated total benefits of EPA regulations (OMB 2017). Most of those benefits stemmed from estimated reductions in mortality caused by lowering emissions of fine particulate matter ($PM_{2.5}$), which are particles less than 2.5 micrometers in diameter or about 30 times smaller than a human hair (EPA 2024a).

But $PM_{2.5}$ control's costs and benefits are unevenly distributed across geographic areas, with some experiencing large net benefits while others have large net costs. Moreover, there are only limited negative externality effects between areas; $PM_{2.5}$ in Los Angeles, where reductions have had large benefits, is not affected by $PM_{2.5}$ emitted in Idaho, where controls have large net costs.

This suggests that $PM_{2.5}$ regulation should be decentralized. General welfare would rise if decisionmakers at the local and regional level—rather than in Washington, DC—would set $PM_{2.5}$ policy and weigh the costs and benefits.

ABOUT $PM_{2.5}$

$PM_{2.5}$ is a regulatory category that covers chemicals and substances emitted by a range of manmade and natural sources, including vehicles, restaurants, factories, power plants, wildfires, windblown dust, and vegetation. These particles are

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thought to penetrate deep into the lungs and bloodstream, potentially causing significant health issues. In the short term, they may aggravate asthma, decrease lung function, and cause difficulty breathing. In the long term, they may create chronic health problems.

Particulate matter, including $PM_{2.5}$, is regulated as one of six "criteria" air pollutants under the Clean Air Act (CAA), with National Ambient Air Quality Standards (NAAQS) setting a permissible exposure level across the United States. The Biden administration lowered the $PM_{2.5}$ standard from 12 to 9 micrograms per cubic meter of air (μg/m³) in 2024.

Over the past century, air quality in the United States has improved substantially, though it is still debated whether the credit goes to the CAA and NAAQS or to pre-existing downward trends, including other environmental policies (EPA 2011a, EPA 2011b, Schwartz and Hayward 2007). In 1960, for example, the annual average total particulate matter concentration in both Los Angeles and Pittsburgh was 143 μg/m³ (EPA 1973). By 1986, levels had fallen to 101 μg/m³ in Los Angeles and 55 μg/m³ in Pittsburgh (EPA 1986). Since 2000, average $PM_{2.5}$ levels have declined by 37 percent.

After decades of improving air quality, are further incremental improvements worthwhile?

REGULATING $PM_{2.5}$: CALCULATING COSTS AND BENEFITS

Rulemakers are not allowed to consider control costs when setting the NAAQS, but federal agencies are required to conduct a cost–benefit analysis for any "economically significant" regulation. Thus, the EPA conducted a Regulatory Impact Analysis (RIA) when it recently changed the $PM_{2.5}$ standards even though the findings technically had no effect on the standard-setting process.

The RIA assessed the health benefits and control costs of lowering the annual average standard for $PM_{2.5}$ to 9 μg/m³ and alternatives of 10 or 8 μg/m³. It found that the benefits of reducing $PM_{2.5}$ to any level dwarf the estimated costs. Both avoided mortality and morbidity were considered, but nearly all benefits (over 98 percent) stemmed from avoided deaths.

The mortality estimates were based on two sources. Wu et al. 2020 implies about 2,100 fewer elderly deaths per year from the new standard, while Pope et al. 2019 estimates 4,500 fewer deaths per year in the entire adult population. Depending on which estimate of avoided mortality is used and the discount rate, the health benefits of changing the standard to 9 μg/m³ were estimated to range from \$20 to \$46 billion per year (in 2017 dollars).

To estimate the costs, the EPA determined which counties would need to reduce $PM_{2.5}$ levels and identified "illustrative" control strategies. According to its estimates, the costs of the control strategies would be about \$594 million per year. Thus, according to the

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EPA, the benefits of the new standard are about 70 to 165 times larger than the costs.

COST AND BENEFITS IN NON-ATTAINMENT COUNTIES

The projected benefits and costs in the RIA rely on assumptions about counties' abilities to control $PM_{2.5}$ emissions. The RIA acknowledges that some counties have historically been unable to achieve previous NAAQS, resulting in their being classified as "non-attainment" areas.

The EPA designates non-attainment status based on a county's design value (DV), a three-year average of annual $PM_{2.5}$ concentrations. The RIA forecasts county annual DVs to 2032. In counties with projected levels above 12 μg/m³—those that are still in non-attainment under the previous NAAQS, implemented in 2012—the EPA identified control strategies to reduce $PM_{2.5}$ concentrations to 12 μg/m³. Of note, the benefits and costs of those reductions were excluded from the RIA's final estimates. The EPA then determined which counties are projected to have $PM_{2.5}$ levels above the new 9 μg/m³ standard and assessed available control strategies.

Requirements imposed by non-attainment reduce output and employment and ultimately cause industries to change behavior in economically inefficient ways.

According to the RIA, only a small number of counties will be affected by the lower $PM_{2.5}$ standard. Out of 3,108 counties in the contiguous United States, only 52 are projected to exceed 9 μg/m³. In the Northeast and Southeast, where counties tend to be smaller, the EPA included emissions reductions in 19 neighboring counties.

The EPA acknowledges that some counties may struggle to meet the new 9 μg/m³ limit. It projects that 25 of the 52 core counties will require reductions beyond the available control strategies. These include Riverside and Plumas counties, CA, where the EPA is unable to identify any strategies for reducing emissions below 12 μg/m³.

As of August 2024, 15 counties were wholly or partially in non-attainment with the 2012 NAAQS, with a combined population of nearly 21 million people. Notably, 13 of those counties have been designated non-attainment areas since the first $PM_{2.5}$ standard was established in 1997. This pattern has been called "institutionalized non-attainment" (Revesz 2022).

COSTS OF NON-ATTAINMENT STATUS

Polluting industries in non-attainment areas face strict regulations that increase the cost of building or expanding facilities. Most importantly, major new emissions sources and major modifications to existing sources are required to meet the most stringent emissions limitation under the CAA—what is known as the "lowest achievable emissions rate"—without any consideration of the costs involved (EPA 2024b). Furthermore, any new emissions must be offset by equivalent or greater emissions reductions elsewhere in the county.

These regulations can impose substantial costs on industries. Becker 2005 found that, on average, manufacturing plants with criteria pollutants in nonattainment areas from 1979 to 1987 experienced abatement costs hundreds of thousands of dollars more than plants in attainment areas (in 1987 dollars). In an analysis of ozone nonattainment between 1972 and 1992, Becker and Henderson 2001 found that the average total costs of plants in ozone nonattainment areas are roughly 4–18 percent higher than in attainment areas, depending on the industry and plant age.

Economic research has also determined that the requirements imposed by non-attainment reduce output and employment and ultimately cause industries to change behavior in economically inefficient ways. Becker and Henderson 2000 analyzed plant data from 1963 to 1992 and found that non-attainment with the ozone NAAQS led polluting industries to relocate to less polluted places and to open smaller plants to avoid the more stringent regulations. Because these shifts were toward less productive areas and required industries to operate at less efficient scales, they created welfare losses that, at least partly, undermine any benefit of the air quality regulation.

Similarly, Greenstone 2002 found that in the first 15 years the CAA was in effect (1972 to 1987), counties in non-attainment with four criteria air pollutants (carbon monoxide, ozone, sulfur dioxide, and total suspended particulates) lost about 590,000 jobs, $37 billion in capital stock, and $75 billion in output (both in 1987 dollars).

Greenstone et al. 2012 estimates that, from 1972 to 1993, total factor productivity decreased by 4.8 percent in counties in non-attainment with the same four criteria pollutants, translating to an annual loss of $21 billion (in 2010 dollars). Looking at the labor effects of the 1990 CAA Amendments, Walker 2013 found that workers at newly regulated plants saw their earnings decrease by 20 percent after their counties were designated as non-attainment, amounting to an aggregate loss of $5.4 billion (in 1990 dollars).

While these studies focus on pollutants other than $PM_{2.5}$, the economic effects of non-attainment are likely to apply to $PM_{2.5}$ as well. The stringent regulations on polluting industries can lead to higher costs, shifts to less-efficient locations or plant sizes, and losses for both industries and workers. The RIA fails to account for these economic costs.

RECENT TRENDS IN $PM_{2.5}$ CONCENTRATION IN PERMANENT NON-ATTAINMENT COUNTIES

Although the EPA recognizes that some counties may remain in non-attainment, it still assumes reductions in $PM_{2.5}$ in 50 of the 52 core counties (excepting Riverside and Plumas). Is this assumption consistent with recent trends?

Since the 2011–2013 DVs—the last period before non-attainment with the 2012 NAAQS was designated—$PM_{2.5}$ levels in many core counties have remained flat or, in some cases, increased. As shown in Figure 1, concentrations in the 13 permanent non-attainment counties did decrease on average after the 1997 NAAQS, but they have generally remained level in the past decade. Between the 2001–2003 and 2011–2013 periods, in those 13 counties the DV on average decreased by roughly 0.58 µg/m³ per year. However, from 2012–2014 to 2021–2023, the average reduction was only about 0.17 µg/m³ per year.

The difference is partly the result of increases in some counties. For example, in Los Angeles County, CA, where a substantial portion of the estimated benefits of the new NAAQS are concentrated, for 2011–2013 the DV was 12.5 µg/m³ while in 2020–2022 it was 13.4 µg/m³. The county's 2021–2023 DV of 12.2 µg/m³ marks the first time since the 2012 NAAQS that its $PM_{2.5}$ concentration dipped below the 2011–2013 level. See Figure 1.

What ultimately matters in the RIA's calculation of benefits is the change in $PM_{2.5}$ level. If the $PM_{2.5}$ DV increases, none of the estimated benefits will occur. But a smaller-than-projected decrease in $PM_{2.5}$ concentration also means that the benefits will be less than estimated. This is, again, particularly important for Los Angeles County. The RIA projects that the county will have a decrease of about 1.3 µg/m³. However, the recent decline to 12.2 µg/m³ is only 0.3 µg/m³ less than the DV in 2011–2013, meaning it has taken the county a decade to lower its DV by less than a quarter of the future reduction projected by the RIA.

This history suggests that the true costs are higher, and benefits are lower, than the RIA's estimates.

COUNTY COSTS AND BENEFITS

According to the RIA, the annual benefits of avoided mortality created by the recent NAAQS change are $22 to $46 billion per year for the Wu et al. 2020 and Pope et al. 2019 health effects, respectively (in 2017 dollars and at a 3 percent discount rate). The annual costs are about $594 million.

However, the RIA and NAAQS focus on reducing $PM_{2.5}$ at the local level and the identified control strategies explicitly forgo any attempt to lower emissions from regional (e.g., power plants) or mobile sources. Thus, it is important to consider whether the regulation passes a cost–benefit test at the county level.

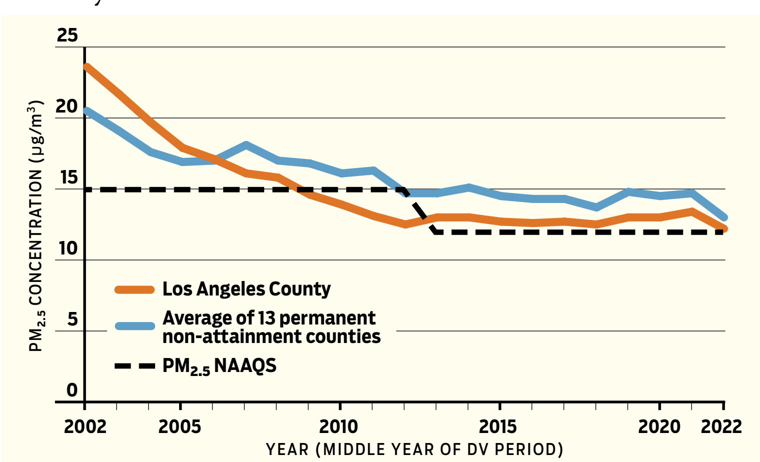
That information has not been publicly released. While the EPA has privately shared data on emissions reductions and costs by county, the county-level breakdown of benefits is not available. Using the data on emissions reductions and roughly following the methods outlined in the RIA, we estimate the annual number of deaths avoided and the monetized benefits in each non-attainment county with projected emissions reductions (50 core counties, excluding Riverside and Plumas) using both the Wu et al. 2020 and Pope et al. 2019 health impacts. Because the 19 neighboring counties identified by the EPA only reduce emissions to help lower ambient $PM_{2.5}$ in an adjacent county, we combine the benefits and costs of neighboring counties into the adjacent core counties. Our full methodology and detailed breakdown of the avoided deaths, benefits, and costs are outlined in Kemp and Van Doren 2025.

In Table 1 we report the point, 2.5, and 97.5 percentile estimates. We estimate net benefits in the range of $1.4–$58.3 billion (based on Wu et al. 2020) and $3.6–$126.1 billion (Pope et al. 2019). These represent the 95 percent confidence interval of the benefits.

Separating the effects by county immediately

Figure 1

Annual Average $PM_{2.5}$ Design Values in Los Angeles County and Permanent Non-attainment Counties



NOTES: Year for design values denotes middle year of calculation period (e.g., "2002" indicates design value from 2001–2003). Average of 13 permanent non-attainment counties is mean design value of Fresno, Kern, Kings, Los Angeles, Madera, Orange, Plumas, Riverside, San Bernardino, San Joaquin, Stanislaus, and Tulare counties, CA, and Allegheny County, PA.

SOURCE: Authors' calculations from EPA Office of Air Quality Planning and Standards, $PM_{2.5}$ Design Values.

highlights that the benefits of regulation are highly concentrated whereas the costs are largely dispersed. The top 10 counties (one-fifth of the 50 included counties) in terms of avoided mortality receive more than 70 percent of the total benefits. These same 10 counties only pay 20 percent of the total costs. Los Angeles County alone receives 25 percent of the total benefits but only bears 2 percent of the costs.

The benefits are not uniform across counties because of population variation. The top 10 counties contain slightly more than half of the total population of the 50 counties. Thus, the same decrease in $PM_{2.5}$ in those counties will be estimated to result in a larger number of avoided deaths. And the control costs in those counties are spread across a larger population. The per capita annual cost in the 10 counties is $5.33.

Table 1

Point Estimates and Confidence Intervals of Annual Avoided Mortality, Benefits, and Costs of Lowering $PM_{2.5}$ standard to 9 $\mu g/m^3$

3 percent discount rate, 2017 dollars

	Wu and colleagues' mortality effects			Pope and colleagues' mortality effects		
	Point estimate	2.5 percentile	97.5 percentile	Point estimate	2.5 percentile	97.5 percentile
Avoided mortality	2,196	1,939	2,453	4,614	3,341	5,884
Total benefits (millions)	$22,503	$2,028	$58,873	$47,281	$4,213	$126,653
Total costs (millions)	$594			$594		
Net benefit (millions)	$21,909	$1,434	$58,279	$46,687	$3,619	$126,059
Benefits in top 10 counties (millions)	$16,540	$1,491	$43,270	$34,707	$3,093	$92,950
Percent of total benefits	74%	74%	73%	73%	73%	73%
Costs in top 10 counties (millions)	$118			$118		
Percent of total costs	20%			20%		
Counties with negative net benefits	4	19	2	3	11	1
Percent of total counties	8%	38%	4%	6%	22%	2%
Total cost in counties with negative net benefits (millions)	$46	$337	$14	$19	$104	$1
Percent of total costs	8%	57%	2%	3%	18%	0%

Source: Authors calculations based on methodology outlined in RIA and cost and emissions information shared by EPA. See description of methodology and county-level breakdown in Kemp and Van Doren 2025 appendix.

The reverse is true of the bottom 40 counties. Lower population means that the estimated benefit of the same reduction in $PM_{2.5}$ will be lower, while the costs are borne by a smaller number of residents. The average per capita cost in the bottom 40 counties is $95.64. On the extreme end is Lincoln County, MT, where $27 million in control costs spread across a resident population of about 22,000 would imply a per capita cost of approximately $1,230 each year.

Those results suggest that the balance between benefits and costs at the county level varies widely. In fact, three or four counties have negative net benefits according to the point estimates of avoided mortality.

If we restrict our analysis to the lowest benefit estimates within the 95 percent confidence interval, the number of counties with negative net benefits increases. At the 2.5 percentile level, 11 to 19 counties (roughly one- to two-fifths) have net negative benefits. These counties account for roughly 20–60 percent of the total costs. The benefits estimated for all counties at the 2.5 percentile are 3.4–7 times the costs while the benefits in the bottom 40 counties are only 1.3–2.4 times the costs. (In the top 10 counties, the 2.5 percentile benefit-to-cost ratio is still 13 to 26.)

Residents of Shoshone County, ID—where the majority of annual $PM_{2.5}$ emissions is dust rather than vehicle emissions, and the costs of control will more than likely exceed the estimated benefits—might have difficulty comprehending why they may be forced to pay more than $900 per year to pave rural dirt roads for little local benefit.

REORIENTING FEDERAL, STATE, AND LOCAL INVOLVEMENT

Should air quality standards be decentralized? The 1970 CAA Amendments established uniform national emissions and ambient air quality standards. However, the uneven geographic distribution of the costs and benefits of further $PM_{2.5}$ regulation and the contrast between dusty rural counties in Idaho and urban counties in Southern California that are in permanent nonattainment suggest that uniform national standards fail to account for local variations in meteorology, geography, urbanization, and industrialization.

National standards are often justified by the existence of interstate pollution. But research shows cross-border negative externalities from $PM_{2.5}$ are declining (Sergi et al. 2020). For example, one study found that in 2011, 41 percent of $PM_{2.5}$-related mortality was attributed to cross-state emissions. The share of cross-state deaths from other pollutants like sulfates and nitrates were higher (77 and 52 percent, respectively) compared to primary $PM_{2.5}$ emissions (35 percent). The study also found that mortality caused by cross-state emissions declined from 2005 to 2011. Separate research found that half of the damages of $PM_{2.5}$ occurred within 32 km (about 20 miles) of the source (Goodkind et al. 2019). More than half of the damages of sulfur dioxide (the precursor of sulfate) occurred more than 200 km (about 125 miles) from the source, whereas more than half of primary $PM_{2.5}$ damages occurred within less than 16 km (10 miles).

Still, $PM_{2.5}$ pollution does have negative effects beyond the immediate local level. But that is not sufficient to justify continued use of a national-level ambient air quality standard. In fact, the NAAQS are not well suited to addressing interstate pollution and, in some ways, *incentivize* it. As Revesz 1997 explains:

> Federal ambient air quality standards are not well-targeted to address the problem of interstate externalities. They are overinclusive because they require a state to restrict pollution that has only in-state consequences. But they are also underinclusive because a state could meet the applicable ambient standards but nonetheless export a great deal of pollution to downwind states (through tall [smoke]stacks or a location near the interstate border). In fact, a state might meet its ambient standards precisely because it exports a large proportion of its pollution.

Furthermore, the EPA itself argues that, because of trends in the constituents and sources of $PM_{2.5}$, efforts to further reduce $PM_{2.5}$ will focus on controlling local sources. In the RIA for the recent $PM_{2.5}$ NAAQS change, it notes:

> Conceptually, $PM_{2.5}$ concentrations in urban areas can be viewed as the superposition of the urban increment and the contributions from regional and natural background sources. The decreases in anthropogenic [sulfate and nitrate] emissions in recent decades have reduced regional background concentrations and increased the relative importance of the urban increment. The projections of additional large reduction in [sulfate and nitrate] emissions … further motivates the need for control of local primary $PM_{2.5}$ sources to address the highest $PM_{2.5}$ concentrations in urban areas. (EPA 2024c)

CONCLUSION

We propose eliminating the $PM_{2.5}$ NAAQS and transferring responsibility for air quality regulation to state governments. The EPA could still offer guidance, research, and technical support, while continuing to regulate interstate and mobile sources of pollution. Considering the generally low $PM_{2.5}$ concentrations in most of the United States and the local focus of future emissions controls, federal regulation of ambient $PM_{2.5}$ is increasingly unnecessary and sometimes bizarre. R

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